EFFECT OF WELDING NUGGET DIAMETER ON THE TENSILE STRENGTH OF THE RESISTANCE SPOT WELDING JOINTS OF SAME SHEETS METAL

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ABSTRACT

Resistance spot welding is commonly used in the automotive industry, because it has the advantage which is high speed, high-production assembly lines and suitability for automation. The welded joints are exposed to the variables of load and pressure, these conditions made the welded joint to rupture. The objective of this project is to study the effect of welding nugget diameter on the tensile strength of the resistance spot welded joints. Using the tensile test method to analyze the selected size of the nugget diameter to determine the maximum load that can be applied before the specimen is rupture or tears apart. By doing the analysis, the suitable size of the nugget diameter can be determined. The materials used in this study are Aluminum and Mild Steel sheet metal and the selected nugget diameter used 4 mm, 5mm and 6 mm because it is varied in the industrial applications.

ABSTRAK

Kimpalan rintangan bintik biasanya digunakan dalam industri automotif, ini kerana ianya mempunyai kelebihan dari segi kelajuan yang tinggi, hasil pemasangan yg tinggi dan sesuai dalam automasi. Sambungan hasil kimpalan biasanya terdedah dengan pelbagai beban dan tekanan, keadaan seperti itu boleh menyebabkan sambungan itu retak. Objektif projek ini ialah untuk mengkaji kesan saiz gumpalan kimpalan yang dikimpal menggunakan kaedah kimpalan rintangan bintik, terhadap kekuatan ketegangan sambungan kimpalan itu. Dengan menggunakan ujian kaedah ketegangan dalam menganalisa saiz gumpalan kimpalan yang terpilih, beban maksimum yang boleh dikenakan sebelum spesimen itu terpisah dua atau retak boleh ditentukan. Dengan melakukan analisa tersebut, saiz gumpalan kimpalan yang sesuai dapat di tentukan. Jenis bahan yang digunakan dalam kajian ini adalah kepingan besi Aluminium dan Besi Halus.dan saiz gumpalan kimpalan yang terpilih ialah 4.0 mm, 5.0 mm dan 6.0 mm kerana ianya digunakan dalam pelbagai industri.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION OF RESISTANCE SPOT WELDING (RSW)

Resistance spot welding (RSW) is a process in which metal surfaces are joined in one or more spots by resistance to the flow of electric current through work pieces that are held together under force by electrodes [2]. The weld is made by a combination of heat, pressure, and time. The process is used for joining sheet materials and uses shaped copper alloy electrodes to apply pressure and convey the electrical current through the work piece. Heat is developed mainly at the interface between two sheets, eventually causing the material being welded to melt, forming a molten pool, the weld nugget. The molten pool is contained by the pressure applied by the electrode tip and the surrounding solid metal. The resistance spot welding has the advantage which is high speed and suitability for automation.

Mechanical testing is an important aspect of weld ability study. Such testing is either for revealing important welds characteristics, such as weld nugget diameter or weld button size, or for obtaining and evaluating the quantitative measures of weld's strength [2]. Mechanical testing of a weldment can be static or dynamic test and among the static test, tension shear or tensile shear testing is commonly used in determining weld strength or the tensile strength of the welded joints because it is easy to conduct the test and the specimens for the test is simple in fabrication.

1.2 IMPORTANCE OF RESEARCH

- To study the effects of the nugget diameter on the tensile strength of the resistance spot welded joints on the sheets metal.
- To estimate the amount of load that could be apply to each different nugget diameter size before the welded joints is fails or rupture.

1.3 PROBLEM STATEMENT

Nugget diameter is one of the important parameters to determine the weld strength of the spot weld before rupture. Different material may show the different effects to the nugget diameter. Aluminum and Mild Steel may have different suitable nugget diameter size for tensile strength endurance limits.

1.4 OBJECTIVE

- To analyze the tensile strength welded joints of aluminum-aluminum sheets metal and mild steel-mild steel sheets metal with the different nugget diameter.

1.5 SCOPE OF RESEARCH

This research is focusing on the effects of welding nugget diameter due to tensile strength of the welded joints of sheets metal. Using tensile test analysis, the tensile strength of the welded joint of sheets metal being evaluated in terms of the maximum load (N) and the displacement of the welded specimens (mm).

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discussed the literatures of the resistance spot welding and the information's about the tensile test analysis.

2.2 RESISTANCE SPOT WELDING

Resistance spot welding is one of the oldest of the electric welding processes in use by industry today, especially in the automotive industry. The weld is made by a combination of heat, pressure, and time. As the name resistance welding implies, it is the resistance of the material to be welded to current flow that causes a localized heating in the part. The pressure exerted by the tongs and electrode tips, through which the current flows, holds the parts to be welded in intimate contact before, during, and after the welding current time cycle. The required amount of time current flows in the joint is determined by material thickness and type, the amount of current flowing, and the cross-sectional area of the welding tip contact surfaces [1].

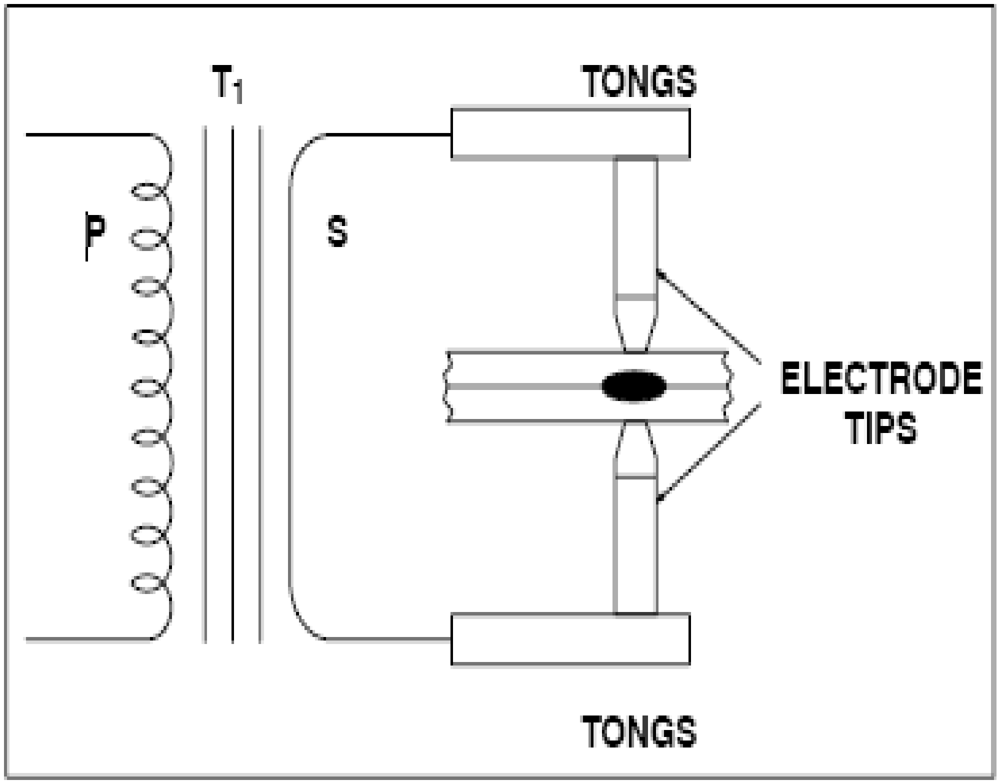

Figure 1: Resistance Spot Welding Machine with Work

The size and shape of the individually formed welds are limited primarily by the size and contour of the electrode faces. The weld nugget forms at the laying surfaces, as shown in **Figure 1**, but does not extend completely to the outer surfaces. In section, the nugget in a properly formed spot weld is round or oval in shape. Spacing between adjacent spot welds or rows of spot welds must be enough to prevent shunting or to limit it to an acceptable amount [1].

2.3 PRINCIPLES OF THE RESISTANCE SPOT WELDING

Resistance Spot Welding is done when current is caused to flow through electrode tips and the separate pieces of metal to be joined. The operation of spot welding involves a coordinated application of current of the proper magnitude for the correct length of time. This current must pass through a closed circuit. The resistance of the base metal to electrical current flow causes localized heating in the joint, and the weld is made.

The resistance spot weld nugget is formed when the interface of the weld joint is heated due to the resistance of the joint surfaces to electrical current flow. In all cases, of course, the current must flow so the weld can be made. The pressure of the electrode tips on the work piece holds the part in close and intimate contact during the making of the weld [1].

2.4 ELECTROTHERMAL PROCESS OF WELDING

In resistance welding, the heat are required to create the coherence is generated by applying an electric current through the stack- up of sheets between the electrodes. So, the formation of a welded joint, including the nugget diameter and the heat- affected zone (HAZ), are definitely depends on the electrical and thermal properties of the sheets and coating materials. The general expression of heat generated in an electric circuit can be expressed as

$$Q = I^2 Rt \quad \textbf{(modification of the Ohm's Law)} \qquad [2]$$

where **Q** is heat (Joule), **I** is current (Ampere) , **R** is electrical resistance of the circuit (ohm,Ω) and **t** is time (second) which is allowed to flow in the circuit. For resistance welding, the heat generation at all location in a weldment is more relevant than, rather than the total heat generated, as heating is not and should not be uniform in the weldment. That means, consideration should more on the heat rate than the total heat, as it will determines the temperature history, and, in turn, the microstructure [2].

For example, considering an aluminum welding, melting may not be happen if the welding current applied is low, due to the low electrical resistivity of aluminum. In general, the electric and thermal process should be considered together in welding.

2.5 SPOT WELDS PARAMETERS

2.5.1 The Parameters

1) Electrode Force

The electrode force is required to squeeze the metal sheets to be weld and joint together. This requires a large electrode force because the weld quality would not be good enough. However, the force must not be too large as it might cause other problems. When the electrode force is increased the heat energy will decrease. So, the higher electrode force needed a higher weld current. When weld current becomes too high, spatter will occur between electrodes and sheets. This will cause the electrodes to get stuck to the sheet.

2) Squeeze Time

Squeeze Time is the time interval between the initial application of the electrode force on the work and the first application of current. Squeeze time is necessary to delay the weld current until the electrode force has attained the desired level [3].

3) Weld or Heat Time

Weld time is the time during which welding current is applied to the metal sheets. The weld time is measured and adjusted in cycles of line voltage as with all timing functions. As the weld time is, more or less, related to what is required for the weld spot, it is difficult to give an exact value of the optimum weld time. For instance:

- Weld time should be as short as possible.
- The weld parameters should be chosen to give as little wearing of the electrodes as possible. (short weld time.).
- The weld time shall cause the nugget diameter to be big when welding thick sheets.
- The weld time might have to be adjusted to fit the welding equipment in case it does not fulfil the requirements for the weld current and the electrode force. (A longer weld time might be needed.).
- The weld time shall cause the indentation due to the electrode to be as small as possible. (a short weld time.).
- The weld time shall be adjusted to welding with automatic tip-dressing, where the size of the electrode contact surface can be kept at a constant value. (a shorter welding time.) [3].

4) Hold Time (cooling-time)

Hold time is the time, after the welding and occurred when the electrodes are still applied to the sheet to chill the weld (time that pressure is maintained after weld is made.). Hold time is necessary to allow the weld nugget to solidify before releasing the welded parts, but it must not be to long as this may cause the heat in the weld spot to spread to the electrode and heat it. The electrode will then get more exposed to wear. Further, if the hold time is too long and the carbon content of the material is high (more than 0.1%), there is a risk the weld will become brittle [3].

5) Weld Current

The weld current is used during welding is being made. The amount of weld current is controlled by two things; first, the setting of the transformer tap switch determines the maximum amount of weld current available; second the percentage of current control determines the percentage of the available current to be used for making the weld. Low percentage of current settings is not normally recommended because it might affect the quality of the weld. Proper welding current can be obtained with the percentage current set between seventy and ninety percent by adjust the tap switch.

The weld current should be kept as low as possible. When determining the current to be used, the current is gradually increased until weld spatter occurs between the metal sheets. This indicates that the correct weld current has been reached. Weld current also influences the value of nugget diameter. Different value of current, it will produce different dimension of the nugget diameter [3].

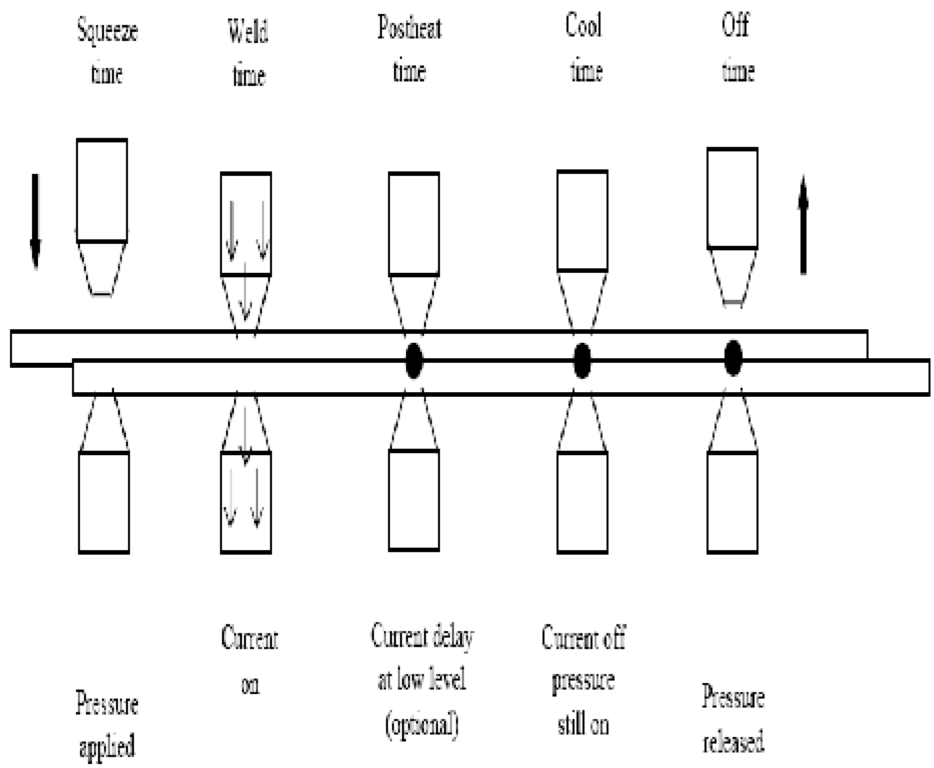

Figure 2: Welding Cycle

The welding processes in resistance spot welding have 5 cycle process as shown in the **Figure 2**. The first cycle is the squeeze time, where pressure from the electrode force is applied to the workpiece. The second cycle is weld time, this process where the current is on and the welding current is applied in the metal sheets to melt the sheet metal for the welding process. Then, postheat time, the current delay at the low level. The fourth cycle is cool time. This cycle allow the melt nugget diameter to solidify before the releasing the welded parts and lastly the off time cycle, the electrode force applied on the sheets metal is released the welding process is done.

2.6 TENSILE TEST

The strength of the welded joints will be analyzed using tensile test method. This method is suitable and simple to test the strength of the welded joint of sheet metal in terms of the tensile strength of the joint before fail or tear apart.

2.6.1 The Tensile Testing

Among statics test, tensile test is commonly used in determining weld strength because of its simplicity in specimen fabrication and testing.

This test consists of pulling in tension to destruction, on a standard testing machine, a test specimen obtained by lapping two strips of metal and joining them by single weld. The ultimate strength of the test specimen and the nature of the fracture, whether by shear of the weld material or by tear of the parent material, and whether a ductile or brittle fracture is obtained, should be recorded.

The most commonly monitored variable in tensile testing is the peak load. However, the displacement at the peak load (maximum displacement) and the corresponding energy should also be monitored, in addition to the peak load. The maximum displacement indicates the ductility and the energy to the energy-absorbing capacity of a weldment. The displacement and energy should be calculated only to the peak load because the failure of the specimen is largely determined at such moments. After the load reaches its peak value, the displacement and energy are generally not unique because of the uncertainty in subsequently tearing the specimens [4].

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discussed the steps in welding the joints and the type of data that would be used to evaluate the tensile strength of the specimens using tensile test method.

3.2 JUSTIFICATION

In this research, the Mild Steel and Aluminum sheet metal are the material that would be used in the resistance spot welding experiment. Both materials are chosen in term of its thermal conductivity and melting points and these properties would affect the tensile strength.

3.3 METHODOLOGY

Below shows the flow chart of the research being made:

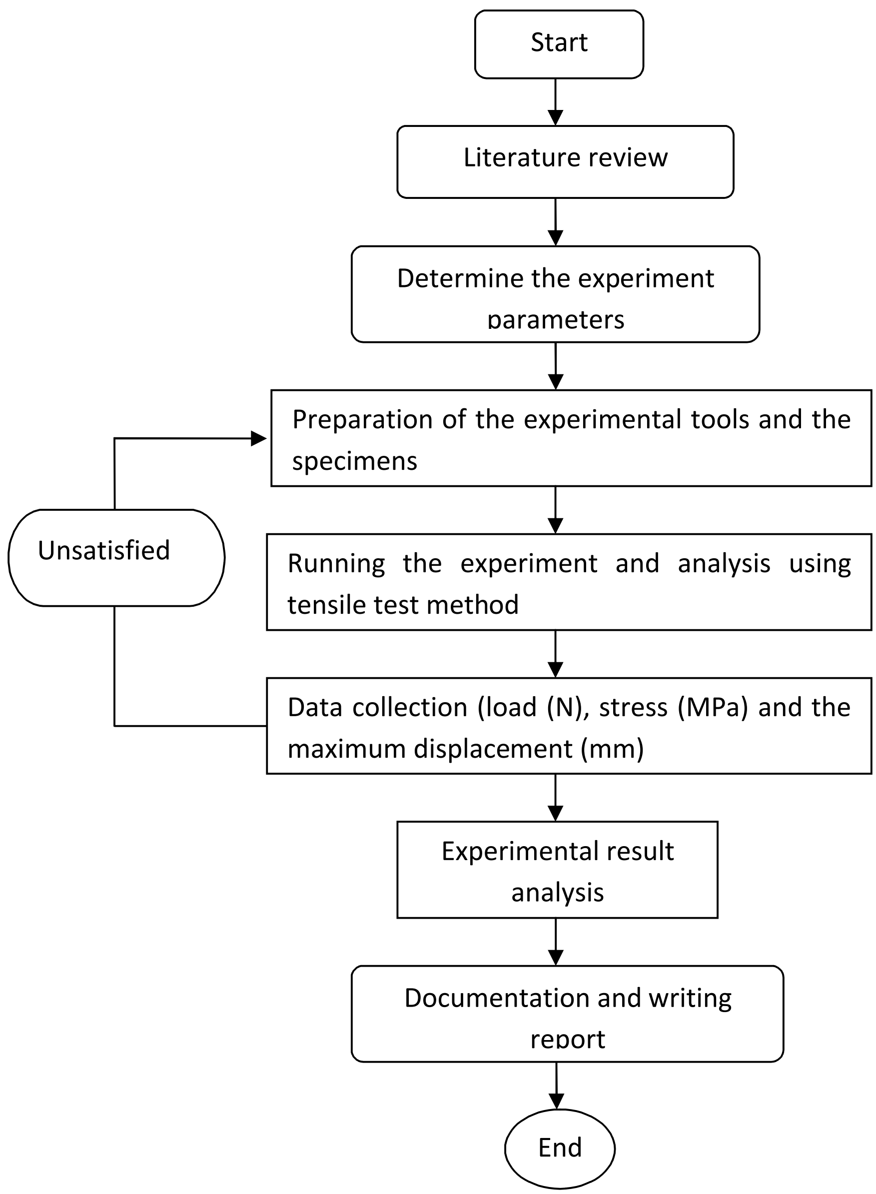

Figure 3: The Flow Chart of the Project

3.4 NUGGET DIAMETER

The main parameter in the experiment is the nugget diameters. This is because different diameter of nugget would shows different tensile strength.

In order to obtain the desired nugget diameter, pre-test would be implemented in resistance spot welding to obtain the correct value of welding current (kA). This is because different welding current would give different value of nugget diameter in spot welding joints.

In this project the desired nugget diameter is 4.0 mm, 5.0 mm and 6.0 mm. Hence, the second parameter is the current welding which affects the value of the nugget diameters.

The 4.0 mm, 5.0 mm and 6.0 mm nugget diameter have being selected because it is suitable for the thickness of the sheet metal. The selected nugget diameter would give better results of tensile strength compares with the nugget diameter of 1.0 mm, 2.0 mm and 3.0 mm. This size is not suitable because the area of joint is too small. The nugget diameter of 4.0, 5.0 and 6.0 mm also varied in industrial applications [7].

Table 1: Welding Currents in Pre-test

Metal Sheet combination	Nugget diameter (± 0.5mm)	Welding current (kA)	Welding Current (second)
Mild-steel with mild-steel	4		
	5		
	6		
Aluminum with aluminum	4		
	5		
	6		

The data during the Pre-test experiment would be record using the table as shown in **Table 1** above.

3.5 WORK PIECE AND MATERIALS

The analysis is uses 2 different materials, which are Aluminum sheets metal and Mild-Steel sheets metal. Each of the specimens dimension is 2.0 cm (width) and 10.0 cm (length). The thickness for both materials is 1.2 mm. The sheets metal will be joint using resistance spot welding. The specimens is combination of same sheets metal which is Aluminum joints with Aluminum sheet metal and Mild Steel joints with Mild Steel sheet metal with the selected nugget diameter of 4.0 mm, 5.0 mm and 6.0 mm.

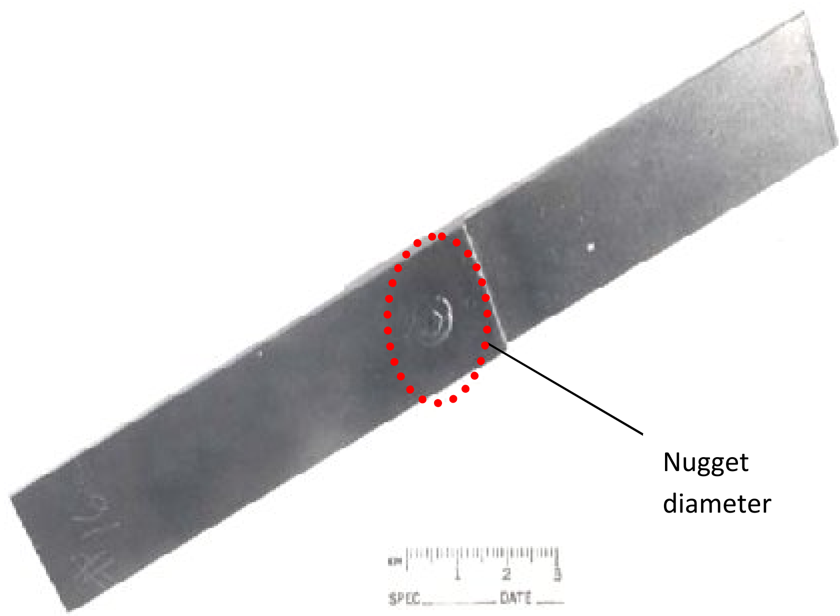

Figure 4: Specimens of Sheets Metal which is Joints Using the Resistance Spot Welding Machine

3.6 DATA COLLECTIONS

Several tables are being used to record the reading during tensile test analysis. The selected data are maximum load (Newton) and the maximum displacement (mm).